International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 10, Issue 2, Apr 2020, 273–284

PERFORMANCE AND EMISSION ANALYSIS OF A DIESEL ENGINE FUELED WITH LEMONGRASS BIODIESEL WITH THE INFLUENCE OF INJECTOR HOLES

SARAVANA KUMAR. M[1], PRABHAHAR. M[2] & PRAKASH. S[3]

[1,3]*Research Scholar, Department of Mechanical Engineering, Aarupadai Veedu Institute of Technology, Vinayaka Mission's Research Foundation, Tamil Nadu, India*

[2]*Professor, Department of Mechanical Engineering, Aarupadai Veedu Institute of Technology, Vinayaka Mission's Research Foundation, Tamil Nadu, India*

ABSTRACT

In diesel engines, injector nozzle geometry and number of holes influence on the working characteristics due to the reason that both the parameters influences the spray factors namely penetration length and droplet size. Therefore, the causes of number of hole in injector on the working feather of a diesel engine utilizing diesel and 20% Lemomgrass oil methyl ester (LGOME20) was experimentally investigated with various engine loads with respect of brake power. The injector with 3, 4 and 5 hole nozzle were used for this study. The output showed that the Nitrogen Oxides (NOx) emission and Brake Specific Fuel Consumption (BSFC), were increased, HydroCarbon (HC), Carbon monoxide (CO) and smoke opacity, emissions were diminished for LGOME20 with 4 hole and 5 hole injector when compared to LGOME20 with standard 3 hole injector.

KEYWORDS: Diesel Engine, Lemongrass Oil Methyl Ester, Performance, Emission & Number of Injector Hole

Received: Feb 01, 2020; **Accepted:** Feb 30, 2020; **Published:** Mar 02, 2020; **Paper Id.:** IJMPERDAPR202024

Original Article

1. INTRODUCTION

For social and economical enhancement, Sustainable source of energy is important. The available conventional energy sources fossil fuels is not sufficient to obtain the demand of high rising energy. The depleting and rising rate of petroleum resources with the increasing emission levels have enables us to search of alternative, renewable, and sustainable diesel fuel. India is one of the highest on oil-consuming nations, and trades about 70% of its oil needs. Per day the consumption of oil totally is 2.8 million barrels. The demand for fossil fuel will increase over the decade and by 2024 nearly 250 million ton is expected [1]. In order to minimize the import of crude oil and to become a self-confident energy sector, India has started using renewable energies in the last three decades [2].

Advantages of renewable fuels are biodegradable and non-toxic when compared to fossil fuels. Using of Renewable energy from non-edible oils lowers greenhouse gas emissions and provides the nation with healthy food and energy protection and sustainable energy efficiency. Usage of Renewable energy derived from non-edible oil decreases Emission of green house gases and it gives enhanced energy security to the country [3,4]. Renewable fuels namely biofuels can therefore be utilized as fuel for both the electricity generation and transport sectors [5,6].

The long term process of engine with neat vegetable oils poses some problems namely coking, carbon deposits and etc. [7]. Though, there are various techniques for minimizing vegetable oil viscosity that contain

blending, preheating, and tranesterification process [8-11] Transesterification of vegetable oils to create esters is usually referred as biodiesel. For bio diesel production, a various number of vegetable oils are utilized which is utilized in the diesel engine applications. They are Rubber seed, Jatropha, Karanja, Mahua, Neem oils and Punnai [12-18].

Hountalas and Zannis [19] numerically studied the effect of injector flow at different injection pressures on the development of combustion and contaminants using a multi-zone combustion configuration on heavy duty diesel engine. Their results revealed that significant enhancements on the output of engines and pollutant emissions. Cenk Sayin et al [20] investigated the engine performance using 2, 4, 6 and 8 hole nozzle injectors. Their results reported that the BTE was enhanced and the smoke opacity, CO and HC emissions is reduced and increased NOx emission due to the increase in injector holes. Gumus et al [21] the performance characteristics of an engine using canola oil methyl ester and its blends with injection timing and pressure effect have been studied. The results showed that when compared to diesel, the combustion characteristics of COME blends were lower. It is also noted that the initial timing of the injection had the best results for BTE compared to advanced and retarded ITs.

Ramadhas et al [22] tested the engine with pure rubber seed oil biodiesel. It is found that lesser blends of biodiesel raise the BTE and reduce in exhaust emissions. Som et al [23] studied the consequences of orifice geometry of nozzle by simulations using CFD software. It is found that the conicity and hydro grinding increases the spray penetration and reducing dispersion resulting the increases the vaporization rate fuel and air.

From survey that very small work has been done on Effect of holes count in the injector on the working characteristics of diesel engines. In this context, the aim of this study is to examine the emission and performance characteristics of diesel engine by 20% LGOME20 blend with the effect of 3, 4 and 5 holes injectors and they compared the results with diesel.

2. MATERIAL AND METHODS

2.1 Preparation of Lemongrass Oil and its Methyl Ester

In this work, Lemongrass oil methyl ester produced from lemon grass oil. Lemongrass (Cymbopogan flexuosus) is a large native aromatic sedge (family: Poaceae) that grows in many components of South East Asia and Africa in tropical and subtropical regions. It grows to about 2 meters and has red base stems. Lemon grass is harvested and dried in sunlight for a week. With the help of mechanical expeller, the oil is extracted from dried grass. In the lemon grass oil and lemon the 10% hexane is added to eliminate the impurities. At 85^{0}C stirring it for 15 minutes and leave it for 30minutes to settle the unwanted organic matter. At low boiling point, the hexane is evaporated and the bottom impurities are eliminated [24]. This oil has sweet smell, lemony, reddish in color and dark yellow to amber with watery viscosity. The chemical parts of such oils are nerol, geranyl acetate, myrcene, traces of limonene and citral [25].

Table 1: Fuel Properties Comparison

Properties	ASTM Standard	Diesel	LGOME
Density (kg/m^3)	D4052	840	830
K.Viscosity @ 40°C (cSt)	D445	3.2	4.34
Specific gravity	D1298	0.83	0.87
Calorific value (MJ/kg)	D240	43	38.79
Flash point (°C)	D93	55	50
Fire point (°C)	D93	63	58
Cetane Number	D976	48	64
Oxygen (%) by wt	D943	-	12

2.2 Test Engine Set Up

In this work, the test was conducted in a dynamic compression ratio with diesel engine multi-fuel capacity and eddy current dynamometer. Table 2 shows the specifications of the test engine. The diesel and biodiesel mixture was contained in a separate fuel tank. A burette and a stop watch method is utilized to compute the fuel flow fed in to the engine in each load. Test was conducted with all the test fuels for different loads, starting from no load to full load condition in the steps of 25%. Figure 1 shows the schematic of test engine. AVL-444 gas analyser considered exhaust gasses, namely CO, CO2, HC, NO and measured smoke opacity using AVL-437C smoke meter. The exhaust gasses such as HC, CO2, CO are measured by infrared calculation and other constituent NO is calculated by the principles of photo chemical sensors. All the instruments are calibrated periodically in reputed testing centers. During the experiment, the data acquisition system was computerized to capture, store and analyze data using different sensors. The engine's performance was analyzed using the online performance and combustion analysis software ' ' Engine soft 8.0 '. '

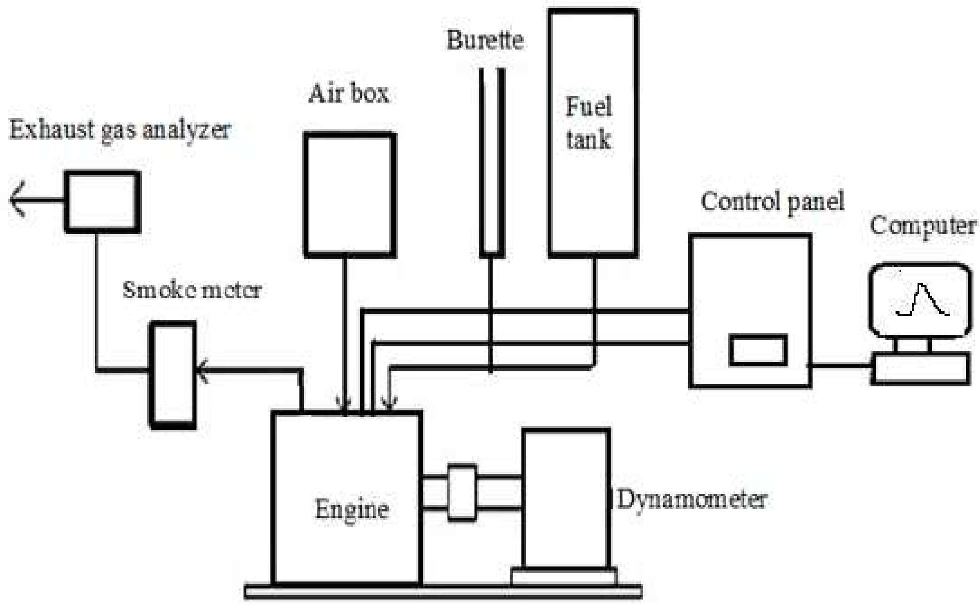

Figure 1: Schematic Test Engine View.

3 Hole Injector **4 Hole Injector** **5 Hole Injector**

Figure 2: Injectors with Varying Numbers of Nozzles.

Table 2: Specifications of the Test Engine

General details	Kirloskar TV-1, 4-Stroke, water cooled, VCR
Rated power	5.2 kW at 1500 rpm
Speed	1500 rpm
Number of cylinder	Single cylinder
Compression ratio	12:1–20:1
Bore	87.5 mm
Stroke	110 mm
Loading	Eddy current dynamometer
Fuel injection pressure	200bar
Injection timing	23°bTDC

2.3 Test Procedure

In this research work, **t**he experiment was conducted in a single cylinder diesel engine with standard injection pressure and timing, and compression ratio at the rated speed of 1500rpm utilizing on diesel and LGBDB20 in order to examine the emission characteristics, combustion and performance. Then the experiment was repeated with the same fuel LGOME20 with 4 hole and 5 hole injectors. Figure 2 shows the fuel injectors with 3, 4 and 5 holes used in the study. The diesel engine was used to drain the fuel in the fuel line after finishing point of each test. The time taken for specified quantity of fuel fed into the engine, exhaust gas emissions and smoke opacity were measured for both the fuels at each load. For the base line data, BTE) and BSFC for diesel fuel were recorded and calculated. In each test all the performance, combustion parameters and exhaust emission values were computed and stored and the results were examined and discussed.

3. RESULTS AND DISCUSSIONS

The experiments were performed with an engine with different injector nozzle holes like 3,4 and 5 holes with loads varying. Every charge the rate of fuel flow, EGT and exhaust gas emissions were recorded for further analysis and the performance were compared with diesel and LGBD20 at standard injector with three hole nozzle at full load.

3.1 BTE

Figure 3 represents the difference of BTE with BP for diesel and LGOME20 with, 4 and 5 hole nozzle. It is noticed that BTE of diesel and LGOME20 with 3hole nozzle is 31.7% and 28.9% at full load. The reduce in BTE for biodiesel blend because of lesser calorific value and high viscosity of the biodiesel blend. The highest BTE was obtained for LGOME20 with 4 hole and 5 hole nozzle is 30.2% and 31.12% respectively. The raise in BTE may be attributed to the more efficient atomization of fuel at five holes which helps to form the homogeneous air-fuel mixture and spray characteristics are retain the presence of the oxygen in the bio diesel which leads to better combustion[19,20]. These results are similar with the researchers Raheman and Phadatare (2004).

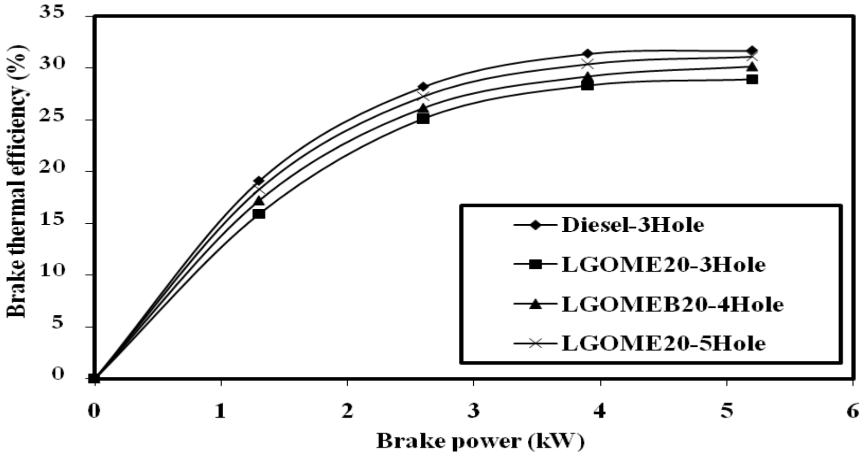

Figure 3: BTE Difference with BP.

3.2 BSFC

The BSFC difference with BP for the test fuel at 3, 4 and 5 hole injector as depicted in Figure 4. The common development of reduce in BSFC with increase in load is experimental for the blends related to the diesel fuel at all the loads [34]. It is noticed that the BSFC obtained for diesel and LGOME20 with 3 hole nozzle is 0.25kg/kWh and 0.29kg/kWh respectively at 100% load. Increase in number of nozzle hole decreases the BSFC value at all loads for biodiesel blend because of better atomization of fuel which enhances the better combination of air and fuel leads to enhanced combustion an thus decreases the BSFC. BSFC obtained for LGOME20 with 4 and 5 hole nozzle is 0.27kg/kWh and 0.26kg/kWh respectively.

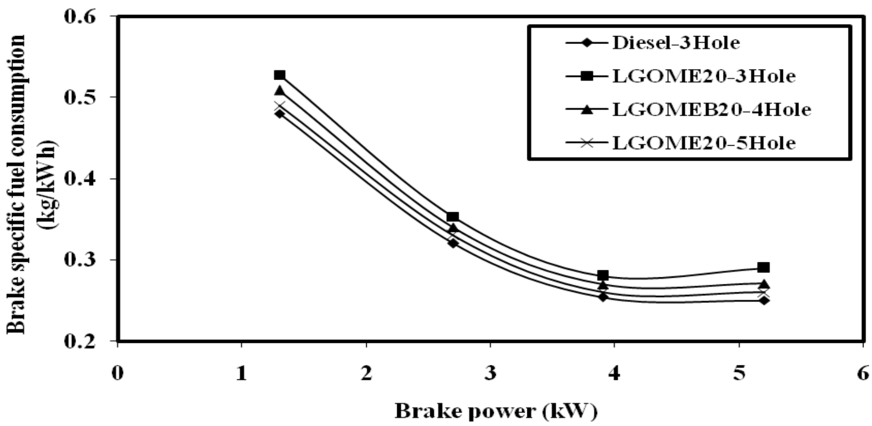

Figure 4: BSFC Difference with BP.

3.3 CO Emissions

Figure 5 depicted the difference in CO emissions with respect to BP for diesel and LGOME20 with 3,4 and 5 hole injectors. Carbon monoxide emission is an odorless, tasteless, and colorless, and the mainly toxic material that is originated in the CI engine exhaust gases. In the compression ignition engine, the CO emission from engine exhaust is lower than in the spark ignition system, since the compression ignition is always worked with a lean mixture CO emissions are observed to reduce with raise in loads as shown in the figure for all test fuels. The CO emission obtained for diesel and LGOME20 with 3 hole nozzle is 0.17% and 0.15% correspondingly at 100% load. The reduction in CO emissions for biodiesel mixture can be due to more oxygen molecule in biodiesel, which helps to promote the oxidation of biodiesel fuel at elevated temperatures during the combustion process. It is also noted that the CO emission was raising with a raise in number of nozzle hole due to improved atomization resulting in a more distributed vapor, and hence improved mixing of air and fuel leads to more effective usage of the biodiesel resulting in reduced CO emissions [26]. The CO emission obtained for LGOME20 with 4and 5 hole nozzle is 0.13% and 0.1% respectively at 100% load. These outputs are dependable with the researchers Ramadhas et al. (2005).

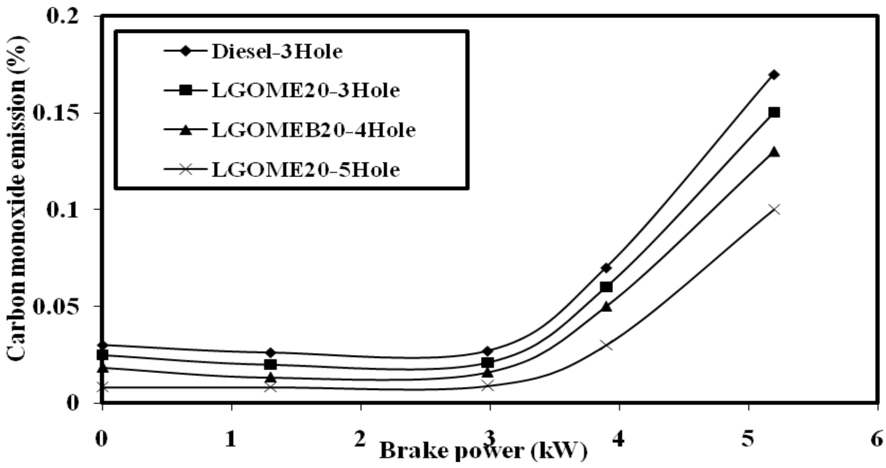

Figure 5: CO Difference with Brake Power.

3.4. Hydrocarbon (HC) Emissions

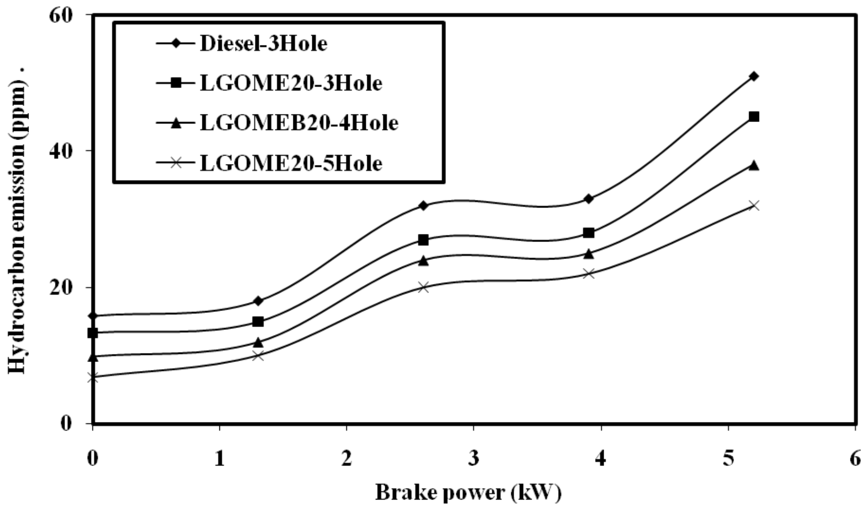

Figure 6: HC difference with BP.

Figure 6 illustrated the HC difference with respect to BP for all the fuels with 3, 4 and 5 hole injectors. This unburnt and partially burnt hydrocarbon is the direct outcome of incomplete combustion in the combustion chamber. It is noticed that HC emissions for diesel and LGOME20 is 54ppm and45ppm respectively at full load. The decrease in HC because of more the amount of O2 in the biodiesel molecule contributes to complete combustion. It is also noticed that HC emissions for LGOME20 with 4and 5 hole nozzle is 38ppm and 32ppm respectively at 100% load. This is because of enhanced atomization vaporization of fuel leads to lower ignition delay outcome in better combustion of biodiesel blend. These results are similar with the researchers Som et al. (2011).

3.5 Nitrogen Oxides (NOx) Emissions

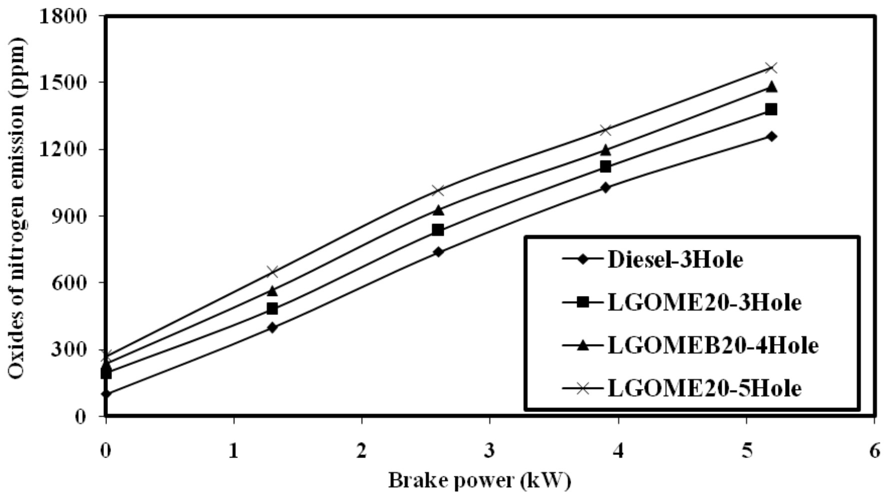

Figure 7: NO Emission Difference with BP.

Figure 7 illustrated the difference of NO emission against BP for the test fuels with 3,4 &,5 hole injectors. Nitrogen oxide emission development in a compression ignition engine is based on the combustion temperature and oxygen availability. It is noted that nitrogen oxide emission for diesel and LGOME20 with 3 hole nozzle is 1260ppm and 1376ppm respectively. The NO emission is high in the case of the biodiesel blend. Due to this, biodiesel includes more oxygen that enhances the combustion method leads to increases the peak combustion temperature. At 100% load the NO emission obtained for LGOME20 with 4 and 5 hole nozzle is 1482ppm and 1568ppm respectively. This is because of more vaporization and atomization of fuel particles by increased number of holes resulting in increase in peak cylinder temperature resulting in increased NOx emissions [21]. Such outputs are in accordance with practical observations of Gumus et al. (2006).

3.6 Smoke Emission

Figure 8 exhibits difference of smoke opacity with BP for diesel and LGOME20 for 3, 4 and 5hole injectors. The smoke formation is due to fuel rich zones and lack of oxygen for combustion. It is noted that at 100% load, the smoke emission obtained for diesel and LGOME20 with 3 hole injector is 69% and 54% respectively. This decrease in smoke emission may be the more due to the presence of oxygen molecule in the biodiesel which enhance the oxidation of fuel and air[27]. Further, the smoke emission was decreased for LGOME20 fuel by increase in number of injector holes. This raise in number of holes may improve the atomization and vaporization of fuel particles which effects good biodiesel combination combustion. The maximum smoke was obtained for LGOME20 with 4 and 5 hole injector is 48% and 38% respectively at

100% load. These outputs are consistent with the experimental observations of Gumus et al. (2006).

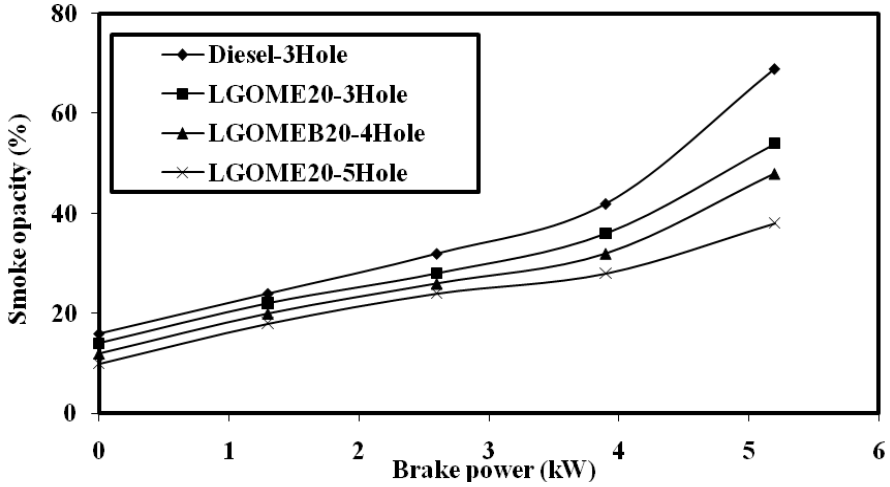

Figure 8: Smoke Opacity difference with BP

4. CONCLUSIONS

In this work, the working characteristics of 20% Lemongrass oil methyl ester-diesel blend are evaluated with 3,4 and 5 holes injector at injection timing and standard injection pressure. From the practical observations, the subsequent conclusions were drawn.

- The BTE for LGOME20 with 5 hole injector is 2.2% higher than that of 3 hole injector when compared to 3 hole injector for the same fuel at 100% load. The BSFC for 5 hole injector is little lesser than the nozzle of having 3 and 4 hole injectors.
- The CO emission of LGOME20 with 5 hole injector is decreased by 33% and the HC emission of LGOME20 with 5 hole injector also decreased by 29% when compared to 3 hole injector.
- The NOx emission of LGOME20 with 5 hole injector is increased by 14% and the smoke emission as also decreased by 44% when compared to 3hole injector at 100% load. Since oxygen is present in the biodiesel and enhanced atomization of fuel by the increased number of holes promotes oxidation of fuel and air leads to better combustion at 100% load.

REFERENCES

1. *Tumbal, A. V., N. R. Banapurmath, and P. G. Tewari. "Effect of injection timing, injector opening pressure, injector nozzle geometry, and swirl on the performance of a direct injection, compression-ignition engine fuelled with honge oil methyl ester (HOME)." International journal of automotive technology 17.1 (2016): 35-50.*
2. *Avinash Kumar, Agarwal,. "Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines." Progress in energy and combustion science 33.3 (2007): 233-271.*
3. *P. G. Tewari and Banapurmath, N. R. "Performance, combustion, and emissions characteristics of a single-cylinder compression ignition engine operated on ethanol—biodiesel blended fuels." Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy 224.4 (2010): 533-543.*
4. *Manickam, A. R., et al. "Experimental analysis of a diesel engine fuelled with biodiesel blend using di-ethyl ether as fuel*

additives." International Journal of Engineering and Technology 6.5 (2014): 2412-2420.

5. *Mohamed Kheireddine Aroua, Atadashi, I. M., and A. Abdul Aziz. "High quality biodiesel and its diesel engine application: a review." Renewable and Sustainable Energy Reviews 14.7 (2010): 1999-2008.*
6. *Syed Ameer, Basha, S. Jebaraj and K. Raja Gopal. "A review on biodiesel production, combustion, emissions and performance." Renewable and sustainable energy reviews 13.6-7 (2009): 1628-1634.*
7. *Rajan, K., M. Prabhahar, and K. R. Senthilkumar. "Experimental studies on the performance, emission and combustion characteristics of a biodiesel-fuelled (Pongamia methyl ester) diesel engine with diethyl ether as an oxygenated fuel additive." International Journal of Ambient Energy 37.5 (2016): 439-445.*
8. *Bari, S., T. H. Lim, and C. W. Yu. "Effects of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine." Renewable energy 27.3 (2002): 339-351.*
9. *Senthilkumar, P., & Sankaranarayanan, G. (2015). Production of waste polyethylene bags in to oil and studies performance, emission and combustion characteristics in di diesel engine. International journal of humanities, arts, medicine and science, 3, 149-158.*
10. *S. Prakash, M. Prabhahar and M. Saravana Kumar “Experimental analysis of diesel engine behaviours using biodiesel with different exhaust gas recirculation rates” International Journal of Ambient Energy, ISSN: 0143-0750 (Print) 2162-8246 (Online), https://doi.org/10.1080/01430750.2020.1712251.*
11. *Nwafor, O. M. I. "The effect of elevated fuel inlet temperature on performance of diesel engine running on neat vegetable oil at constant speed conditions." Renewable energy 28.2 (2003): 171-181.*
12. *Annamalai, Ravichandran, Rajan Kuppusamy, and Ramachandran Senthilkumar Krishnan. "Effect of piston bowl geometry and different injection pressure on the performance, emission and combustion characteristics of diesel engine using biodiesel blend." Thermal Science 22.3 (2018): 1445-1456.*
13. *Raheman, H., and A. G. Phadatare. "Diesel engine emissions and performance from blends of karanja methyl ester and diesel." Biomass and bioenergy 27.4 (2004): 393-397.*
14. *Rajan, K., and K. R. Senthil Kumar. "Performance and emissions characteristics of a diesel engine with internal jet piston using biodiesel." International Journal of Environmental Studies 67.4 (2010): 557-566.*
15. *Raheman, H., and S. V. Ghadge. "Performance of compression ignition engine with mahua (Madhuca indica) biodiesel." Fuel 86.16 (2007): 2568-2573.*
16. *Rao, N. D. P., Krishna, M. M., Prasad, B. A., & Murthy, P. The effect of thermal barrier coating on exhaust emissions and combustion characteristics of diesel engine with rice brawn oil based biodiesel. International Journal of Research in Engineering and Technology, ISSN (E), 2321, 8843.*
17. *Prabhu, L., et al. "Combustion, performance and emission characteristics of diesel engine with neem oil methyl ester and its diesel blends." American Journal of Applied Sciences 10.8 (2013): 810-818.*
18. *Senthil, Kumar Srinivasan, Krishnan Purushothaman, and Kuppusamy Rajan. "Performance analysis of compression ignition engine using rubber seed oil methyl ester blend with the effect of various injection pressures." Thermal Science 20. suppl. 4 (2016): 1083-1090.*
19. *Nanthagopal, K., B. Ashok, and R. Thundil Karuppa Raj. "Influence of fuel injection pressures on Calophyllum inophyllum methyl ester fuelled direct injection diesel engine." Energy Conversion and Management 116 (2016): 165-173.*
20. *Nwafor, O. M. I., G. Rice, and A. I. Ogbonna. "Effect of advanced injection timing on the performance of rapeseed oil in diesel*

engines." Renewable energy 21.3-4 (2000): 433-444.

21. *Raheman, H., and A. G. Phadatare. "Diesel engine emissions and performance from blends of karanja methyl ester and diesel." Biomass and bioenergy 27.4 (2004): 393-397.*
22. *Naik, R. T., & Nilesh, C. (2016). Emission characteristic of a high speed diesel engine. International Journal of Mechanical Engineering, 5, 29, 36.*
23. *Hountalas, D. T., and T. C. Zannis. "Effect of injector flow rate on heavy-duty DI diesel engine performance and emissions for various injection pressures." International journal of vehicle design 41.1-4 (2006): 103-126.*
24. *Metin Gumus, Sayin, Cenk, and Mustafa Canakci. "Influence of injector hole number on the performance and emissions of a DI diesel engine fueled with biodiesel–diesel fuel blends." Applied thermal engineering 61.2 (2013): 121-128.*
25. *Gumus, Metin, Cenk Sayin, and Mustafa Canakci. "Effect of fuel injection timing on the injection, combustion, and performance characteristics of a direct-injection (DI) diesel engine fueled with canola oil methyl ester− diesel fuel blends." Energy & fuels 24.5 (2010): 3199-3213.*
26. *Ragit, S. S., S. K. Mohapatra, and K. Kundu. "Performance and emission evaluation of a diesel engine fueled with methyl ester of neem oil and filtered neem oil." (2010).*
27. *Som, Sibendu, et al. "Effect of nozzle orifice geometry on spray, combustion, and emission characteristics under diesel engine conditions." Fuel 90.3 (2011): 1267-1276.*
28. *K. Vijayakumar Reddy, Hariharan, V. S., and K. Rajagopal. "Performance, emission and combustion characteristics of Sea lemon oil and its diesel blends in a diesel engine." International Journal of Agricultural and Biological Engineering 2.3 (2009): 69-75.*
29. *Sriram, V., Jeyajeevahan, G., Brittojoseph, G., & Durairaj, R. (2017). Engine Performance and Emission Characteristics of 1-Octanol Blended Bio-diesel in a Single Cylinder Diesel Engine. Stroke, 2000, 110.*
30. *Sathiyamoorthi, R., et al. "Experimental investigation on performance, combustion and emission characteristics of a single cylinder diesel engine fuelled by biodiesel derived from Cymbopogon Martinii." Renewable Energy 132 (2019): 394-415.*
31. *S. Prabhakar, S. Ashf Aque Ahmed, Binu K. Soloman and C. Jagdeesh Vikram. 2013. Performance test forLemon grass oil in single cylinder diesel engines. ARPN Journal of Engineering and Applied Sciences. Vol.8 (6), pp. 455-458.*
32. *Dhivagar, R., S. Sundararaj, and V. R. Vignesh. "Biodiesel from lemon and lemon grass oil and its effect on engine performance and exhaust emission." IOP Conference Series: Materials Science and Engineering. Vol. 330. No. 1. IOP Publishing, 2018.*

AUTHOR'S PROFILE

M. Saravanakumar is currently pursuing Ph.D in Mechanical Engineering and the title of his research is Biodiesel. He obtained his under graduation in BE Automobile Engineering at MIT Anna University in 2005 and obtained his master degree Manufacturing Engineering in Year 2013 at MIT Anna University, He has registered for Research at Vinayaka

Mission Research Foundation. He has written and presented more than Ten research papers in national and international journals.

Dr. M. Prabhahar obtained his Under Graduation in BE Mechanical Engineering at Jayamatha Engineering College, Nagercoil. He studies in MepcoSchlenk Engineering College, Sivakasi for his Post Graduation. He has registered for Research at St Peters University, Chennai. At the time of submission of his thesis, he had fifteen publications to his credit. He acquired his Ph.D for his research work in the area of IC Engines performance and Emission Control using alternate fuels. His assiduous and prolific research work has earned him very good reputation in the field of bio alternate fuels. He has 142 citations in the International Journals including Springer, Taylor and Francis and IEEE proceedings. He was a member of several technical executive committees on National and International conferences and potential reviewer of several journals which in turn reviewing minimum four papers per month. His research paper “Modeling and construction of bio diesel processor”, has been selected for the cover note article for the Global Journal of Research in Engineering, USA. To his credit, he has more than 60 publications in reputed journals and has h-index as 7. He is also extending his meritorious service of being referee of many reputed journals. He is currently working as Professor in Mechanical Engineering Department, Aarupadaiveedu Institute of technology, Paiyanoor, Chennai.

S. Prakash is currently pursuing Ph.D in Mechanical Engineering and the title of his research is Biodiesel. He obtained his under graduation in BE Mechanical Engineering at Er. Perumal Manimekalai College of Engineering, Hosur, Anna University in Year 2008 and obtained his master degree in Manufacturing Engineering in the Year 2013 at MIT Anna University, He has registered for Research at Vinayaka Mission Research Foundation. He has written and presented more than Fifteen research papers in national and international journals.